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ABSTRACT

This bulletin is intended as a resource for school system facility planners and architects who design schools. Ways in which decision makers can incorporate environmental concerns in the design of school buildings are detailed. Focus is on the design of interior partition systems. Partition systems in schools serve several purposes; they define space, provide acoustical privacy, and myriad other functions. Some traditional criteria for such partitions, along with some building ecology criteria, are detailed. Various partition types such as concrete masonry unit partitions, gypsum wallboard over metal studs, straw panels, and operable partitions are described. Different features of each partition type, such as environmental issues, maintenance, and repair, are provided. Recommendations for what to look for in a particular partition system are offered. A decision-making process is outlined, which features various criteria: durability, cost, acoustics, flexibility, maintenance, recycled content, embodied energy, indoor air quality, and raw materials. In conclusion, although there is no perfect system for building partitions in schools, the most commonly specified systems are relatively favorable from an environmental standpoint. (Contains two figures, one table, and two references.) (RJM)

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TECHNICAL BULLETIN

Building Ecology and Partition Design

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Technical Bulletin Intent

The purpose of the building ecology technical bulletin series is to explore the incorporation of environmental concerns into the design of school buildings. This bulletin will address the design of interior partition systems. It is intended to be a resource for school system facility planners and architects who design schools.

Building Ecology

All acts of building have environmental consequences. Building ecology is a term that describes the interrelationships between people, the built environment, and the natural environment.[1] Included in the study of building ecology are consideration of:

- atmospheric impacts
- water use and water quality
- resource conservation and depletion
- biodiversity conservation and reduction
- human health effects
- energy use
- land use
- waste generation
- soil pollution
- socio-economic impacts[2]

These impacts can occur at any stage in the life cycle of a material or assembly, from the acquisition of raw materials through their incorporation into the useful life of a building; and ultimately to demolition or reuse. For more information on building ecology in general, see the previous technical bulletin, Building Ecology and School Design (November 1995)[3] and the reference section at the end of the bulletin.

Building Ecology and School Design

Building ecology has special relevance for school design because our end-users are predominantly children and our mission is education. Children are more susceptible to adverse health effects from indoor environmental pollution than adults. A safe and appropriate learning environment enhances the educational process. While the immediate health and safety of our children are the most immediate factors, broader issues are also important. We teach students critical thinking skills so that they may make informed decisions about themselves, society, and the environment. Those of us who make decisions for students must hold ourselves to the same standards.

Partition Systems

Partition systems in schools serve several purposes: defining space, providing acoustical privacy, separating activities, and separating areas in the case of fire. Some partitioning of space may be accomplished by load bearing walls. This bulletin is limited to non-load bearing systems. Partition systems will be described as general types, improvements in the environmental performance of each type will be explored, and the different types will be compared.

Evaluation of partition types will include both traditional and ecological factors. If a partition system is environmentally benign but does not meet a school system's basic performance demands, it will not be selected by school systems. The following criteria have been developed to specifically describe performance demands for partitions in school buildings:

Traditional Criteria

- durability
  - impact resistance
  - imperviousness
  - life expectancy
- cost
  - initial cost
  - indirect costs such as added structure due to weight
  - maintenance costs
  - repair costs
- flexibility
  - portability
  - demountability
  - versatility
- fire rating
- maintainability
  - wear layer longevity
  - cleanability
  - vandal resistance
- acoustics
- aesthetics

Building Ecology Criteria

- materials acquisition impacts
  - recycled content
  - renewable or finite resource use
  - water, air, and soil pollution
- manufacturing impacts (production, packaging, and transportation)
  - water, air, and soil pollution
  - energy use
  - waste generation
- installation and use impacts
  - worker safety
  - waste generated during installation
  - thermal performance
  - durability
  - indoor air quality
- maintenance and the environment
  - cleaning
  - coatings
  - frequency of replacement
- embodied energy
- reusability
  - demolition
  - second-life uses
  - disposition

Partition Types

A. Concrete Masonry Unit Partitions

Description

Concrete masonry units (CMU) are the most frequently specified partition system in school buildings. Pre-cast hollow blocks are made of cement, aggregate, and water. Many variations to the basic formula are also available. A CMU partition may be painted, covered with ceramic tile, or glazed. CMU construction provides durable, cost-effective, fire proof and relatively sound-proof construction. Sound transmission through CMU is acceptable

for most school applications, with a sound transmission coefficient (STC) ranging from 41 to 48 for a typical partition.

A CMU partition is heavier than most other systems, requiring greater supporting structure underneath.

Environmental Issues

From an environmental standpoint, CMU construction has varied impacts. The component ingredients are finite but abundant. The materials acquisition phase involves open-pit mining operations to obtain limestone, sand, gravel, and other components. Mining impacts include:

- fuel combustion, leading to Volatile Organic Compound (VOC) emissions, ground-level ozone, greenhouse effect, acid rain, and particulate release.
- tailings waste, leading to runoff and loss of biodiversity.
- land disturbance, leading to soil erosion and habitat alteration.

These impacts apply to acquisition of limestone, gypsum, clay, mud and iron ore for mortar as well.[4] CMU can be manufactured with recycled content, including pre- or post-use CMU.

Preparation of materials for forming concrete masonry units involves crushing, screening and processing of components, resulting in particulate release and fuel consumption. The manufacture of cement, and of the key ingredients, involves energy consumption and heat generation in addition to particulate release. Fly ash, a waste product from coal production, can be used to replace up to 25% of the cement used in CMU manufacture. The processed components are mixed with water and formed in molds. They are then cured at an elevated temperature. Transportation is a factor at each stage. Transportation of CMUs and component parts does not pose extraordinary concerns other than those associated with the burning of fossil fuels. Lighter weight CMUs require less fuel per area of finished wall to transport. Because CMUs are heavier than the other materials discussed here, fuel consumption for transporting them has a greater impact on the environment, provided the distances are equivalent.

During construction, scrap CMU is generated. Scrap can be recycled as aggregate for road bed or other uses. Recycling operations are increasingly available to collect construction debris.

Indoor air quality is not an issue for CMU construction. The American Institute of Architects Environmental Resource Guide (ERG) cites a 1988 study measuring the emissions of VOCs from concrete unit masonry ranging from 0.006 to 0.036 µ/ft². This is considered to be a very low-emitting material.[5] The emissions consisted of aromatic hydrocarbons and halogenated hydrocarbons. The painting of CMU adds indoor air quality concerns. Epoxy paints add additional concerns because of the quantity and quality of offgasing associated with many epoxy paints. Lower VOC water-based epoxies are being introduced, however.

Ceramic tile, sometimes used as a wainscot, has environmental costs associated with its acquisition and manufacturing stages. The greatest of these is the additional heat generated by firing. Once ceramic tile is installed, it has minimal negative environmental consequences.

Glazed CMU is coated and fired at the factory. While this process involves heat generation, it is more durable than a ceramic tile wainscot. It is also more cost-effective. Many schools use a base course of glazed CMU topped by conventional painted CMU for high traffic areas.

Maintenance and Repair

CMU partitions will last the life of the building. Their impact resistance makes them uniquely appropriate for schools. On the other hand, CMU partitions are difficult to reconfigure. Power and other cabling cannot be threaded through existing walls.

Recommendations for Specifying CMU

- Specify CMU with recycled content.
- Glazed CMU is recommended for its IAQ performance over painted CMU, although its embodied energy is greater.
- Ceramic tile does not appear to have any advantage over glazed CMU for most school locations.
- Specify lightweight CMU to reduce the amount of material used, the environmental costs of shipping, and the amount of additional structure required to support the partition.
- If paint is the finish of choice, use the least toxic paint that will meet the need. Many paint and coating companies are advertising low-VOC products, even for high demand locations.[5] Medium VOC-emitting paint may be justified only where its longevity justifies the higher emissions, and only where the school will be vacated during and for a minimum of 48 hours after application.
- Use the thinnest block suitable for the location. For schools, this usually means no less than 6" block.

B. Gypsum Wallboard Over Metal Studs

Description

Gypsum wallboard systems, while ubiquitous throughout the construction industry, are less often specified for school buildings. Their advantages of first cost, ease of installation, light weight, and flexibility are outweighed by their limited resistance to impacts.

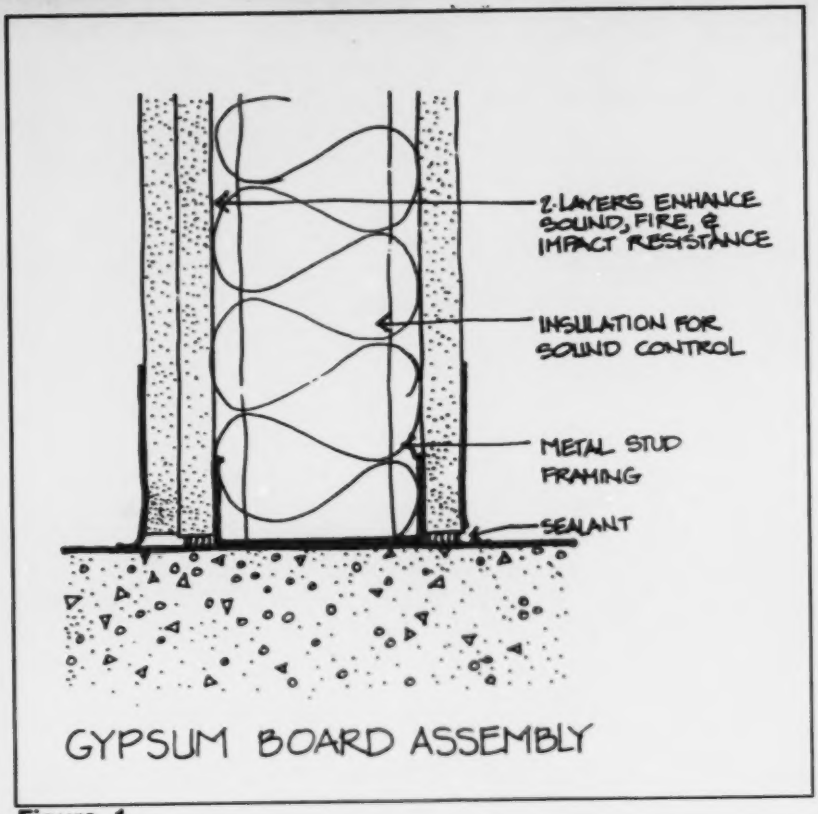

Figure 1

The components of this system include metal stud framing, gypsum wallboard (or a variation), joint compound or veneer plaster, metal screws, drywall tape, and paint. In some locations, gypsum wallboard may be doubled to improve fire rating and/or durability. In schools, a fiberglass insulation blanket is often added to reduce sound transmission between adjacent spaces. Gypsum board is made of gypsum sandwiched between two layers of paper. Variations include panel board products made with recycled content, including newsprint. (Figure 1)

Environmental Issues

According to the AIA Environmental Resource Guide, gypsum is in plentiful supply. Negative impacts associated with mining or quarrying operations include:

- soil erosion and habitat destruction
- water siltation from runoff
- particulate emissions
- air pollution from petroleum-powered extraction equipment.

Gypsum is available throughout the United States, but is sometimes imported. The paper facing covering both sides is often made using recycled paper; use of virgin paper for facings increases the magnitude of negative environmental impacts resulting from the harvesting and processing of trees. These impacts include:

- depletion of forests (virgin paper only)
- effluent from pulping which may include organics, toxics, and dioxins (both new and recycled content)
- air emissions which may include SOx, NOx, CO, CO^2, VOCs, particulates and chloroform (new and recycled)
- energy consumption (30% less for recycled paper)[7]

Joints between boards are taped with paper tape. Fiberglass tape is available, but not widely used. Impacts are similar to those described for the paper facing, above.

Joint compound is spread over joints and fastener heads to make a smooth surface for painting. Compound comes premixed or powdered. According to the Environmental Resource Guide, joint compound contains limestone and gypsum. Additives may include polyvinyl acetate, natural or synthetic starches, mica, clay, talc, perlite, ethylene glycol, and anti-bacterial and anti-fungal agents. Pre-mixed joint compound usually contains more synthetic additives than powdered mix does.

During installation, sanding of joint compound creates significant particulate emissions. Equipment is available to minimize dust. Respiratory protection is worn by installers. Paint is the typical finish for gypsum wallboard systems. Vinyl base is usually applied. Because of the variety of formulations available, paint is highly variable in terms of its environmental performance. A key consideration in schools is indoor air quality. Low-VOC paints, usually water-based, degrade indoor air quality less than oil-based formulas.

Maintenance and Repair

Maintenance of gypsum wallboard systems typically involves maintaining the painted finish. Gypsum partitions can be altered with greater ease than CMU. They can be removed with relative ease, but not reused. Gypsum board's primary liability for school use is its vulnerability to dents and breaks.

Recommendations for Specifying Gypsum Wallboard Systems

- specify gypsum board with recycled paper facings and recycled content
- specify powdered joint compound rather than pre-mixed
- consider alternatives to traditional fiberglass batts for sound control: these include new products with less brittle glass filaments, and insulation

made of recycled cloth
- specify low-VOC paints, and follow best application practices to protect indoor air quality
- gypsum board installation waste can be ground on-site and used as a soil amendment, especially to condition clay-type soils. This could be possible for post-use gypsum board as well, but removal of paint layers and possible asbestos additives in old gypsum board complicate the process considerably

C. Straw Panels

Description

A less familiar product marketed as an environmentally responsible alternative to gypsum wallboard systems is made of waste straw sandwiched between paper facings. The finished panels are 2 1/4" thick, 4 feet wide, and up to 12 feet long. The straw is heated and compressed through metal plates. The heat causes the straw to release its own resins, bonding the assembly into a rigid panel. The panels are prefitted with interior channels for wiring, and can be cut for outlets and wall configurations. Panels rest on a wood nailer and clip together. They can be finished like drywall.

In traditional terms, straw panels perform unevenly. The cost of straw panel systems is slightly higher than gypsum wallboard. One straw product carries a sound transmission rating of 33[8], which is lower than many school functions demand. Because of the monolithic nature of the material, sound blankets can not be added without furring out one side. The same product lists a flame spread rating of 60 (ASTM E-84) with a smoke density rating of 25, making it a Class II material and limiting its use to appropriate areas. Its impact resistance is substantially better than single or double layer gypsum board assemblies.(Figure 2)

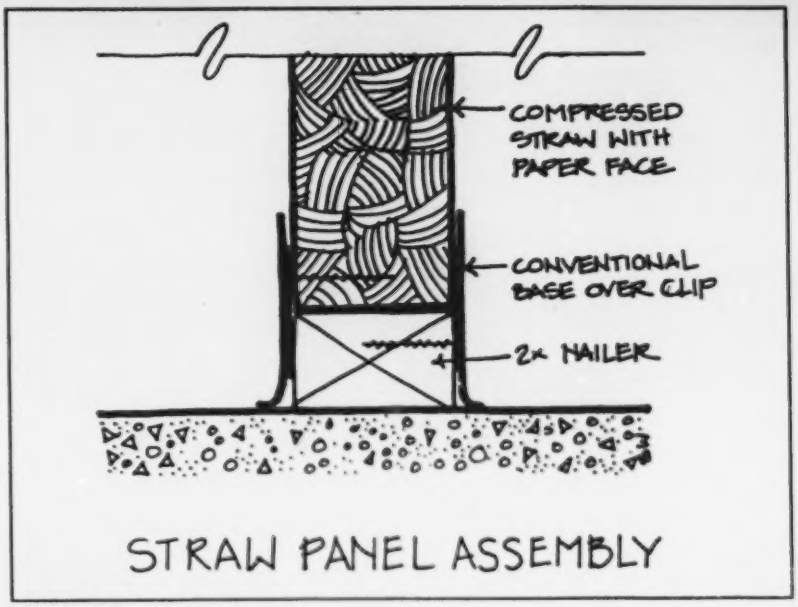

Figure 2

Environmental Issues

The straw partition system is made using straw that would otherwise be considered waste. This has several benefits: first, it makes use of a renewable, abundant resource; second, it reduces the need to strip mine for gypsum for conventional wallboard and ore for steel; and third, it gives farmers a greater return on their crops, having a socio-economic benefit.

Figures on embodied energy are not available, but the minimal processing indicates that energy consumption is low, except for transportation costs. Panels are heavy (140 pounds each) and the panels are not manufactured widely.

Testing for emissions from the panels has not been done comprehensively. A test for formaldehyde emissions has shown no detectable levels of formaldehyde.[9] During installation, some straw dust is generated. Assuming the edges are sealed, the straw panels' impact on indoor air quality would depend on the type of paint applied. Performance might match gypsum wallboard with the same finish.

Maintenance and Repair

The straw panel systems have maintenance requirements similar to gypsum wallboard systems. Because of the density of the straw panels and their monolithic nature, their impact resistance is much better than that of gypsum board. Dents can be repaired with drywall compound. The precut wiring channels make the panels more difficult to modify to suit changing requirements.

Recommendations

- Ask for VOC emission information on the panels themselves
- Use joint compounds and veneer plasters with fewer synthetic additives that contribute to emissions
- Use low-VOC paints

D. Operable Partitions

Description

Operable partitions are often specified between classrooms to provide large group spaces without building dedicated rooms for two or three classes to share. These partitions are expensive, and less durable than conventional fixed partitions. As a result, they tend to be specified sparingly.

Operable partition systems are made of an underlying steel structure with foam insulation and a nylon or vinyl outer covering. They have rubber or synthetic seals at the bottom and hinges between panels. They typically fold when open. Sometimes chalk or tack board are applied to one or both faces. They are suspended from the ceiling by means of a beam, a track, and a trolley device. The beam is usually boxed in with a gypsum board bulkhead. Some folding partitions are motorized; these are usually reserved for large spaces such as gymnasiums.

Operable partitions can be specified in a range of STC ratings suitable for most school functions. They are typically not fire-rated, and therefore cannot be specified where a fire separation is required.

Environmental Issues

Operable partitions are resource-and energy-intensive to manufacture. Their environmental benefit, if any, lies in their ability to create dual-function spaces. If the ability to turn two 800 square foot classrooms into one 1600 square foot assembly area avoids the construction of 1600 square feet of additional area, then its environmental contribution is great in terms of avoided impacts.

Maintenance and Repair

Because operable walls have movable parts, their maintenance and lifecycle burden is heavy. The more often a partition is used, the shorter its life will be. The floor seals are particularly subject to wear. Partitions can be damaged by improper operation. The life expectancy of operable wall systems varies considerably from one installation to another.

Recommendations

- Specification of an operable wall system should be justified by its contribution to the educational program.
- If the surface of the partition is absorbent, specify its installation after painting of surfaces in the vicinity has been completed for at least 48 hours.

Outline of Decision-Making Process

The preceding discussions evaluate partition systems in isolation. How does one compare one system to another? The task is a difficult one. Manufacturers do not provide parallel information on quantifiable issues such as embodied energy and VOCs. Further, partition systems are assembled using numerous components. Partition assemblies can therefore vary widely within an overall category. Further, the state-of-the art lifecycle analysis, which could tell us how to weigh one impact against another, does not exist in a widely accepted form. Architects and planners, therefore, must work to assess priorities within the constraints of imperfect information.

In the example that follows (Table 1), criteria are established based on information available. Only materials which meet traditional criteria are included. Criteria are identified based on the availability of information and its relevance to schools. Points are assigned for each criteria based on explicit scoring. In our example, durability, cost, and indoor air quality are given greater weight than the other criteria. This approach might be used for hallways and high use areas. In classrooms, durability and indoor air quality are important, but flexibility may be of equal importance. An adjustment to the evaluation system might add a weight factor of 2 or 3 to the flexibility criteria and reduce the weight of the durability criteria to a factor of 2. The system with the highest total score could be considered as the optimal one for a particular function. In administrative areas, functional demands are less stringent; and environmental issues may be able to play a greater role in the selection process. This role would be reflected by applying greater weight to these criteria.

CRITERIA:

DURABILITY:

Range

1 = short life span (20 years or less), easily damaged, difficult to repair
2 = medium life span (20 to 40 years), easily damaged, repairable
3 = long life (40+ years), maintenance required
4 = long life (40+ years), little or no maintenance required

COST:

Range

1 = cost/linear foot ≥ $100
2 = cost/linear foot ≥ $50 ≤ $100
3 = cost/linear foot ≥ $25 ≤ $50
4 = cost/linear foot ≤ $25

ACOUSTICS:

Range

1 = STC of 35 or less
2 = STC of 35 to 40
3 = STC of 40 to 45
4 = STC of 45+

FLEXIBILITY:

Range

1 = no flexibility: partition cannot be amended
2 = limited flexibility: partition can be altered in place
3 = moderate flexibility: partition is designed to be alterable; is modular or otherwise allows for change
4 = complete flexibility: designed to be moved regularly without special tools or skills

MAINTENANCE:

Range

1 = complex or intensive maintenance, difficult to repair
2 = regular maintenance required; repairs are difficult
3 = moderate maintenance required; repairs are possible
4 = little maintenance required; repairs are easy

RECYCLED CONTENT:

Range

1 = no recycled materials
2 = limited pre-consumer recycled materials
3 = limited pre- and post-consumer recycled materials
4 = significant recycled material content

EMBODIED ENERGY:

Range

1 = very high embodied energy (over 4,000,000 Btu/100 square feet)
2 = high embodied energy (3,000,000 to 4,000,000 Btu/100 square feet)
3 = moderate embodied energy (2,000,000 to 3,000,000 Btu/100 square feet)
4 = low embodied energy (less than 2,000,000 Btu/100 square feet)

INDOOR AIR QUALITY:

Range

1 = significant IAQ problems during building occupancy
2 = significant IAQ concerns during installation only
3 = minor IAQ issues during any phase, which can be mitigated
4 = no IAQ concerns

RAW MATERIALS:

Range

1 = 100% finite resources, in limited supply
2 = finite resources, mostly in abundant supply
3 = renewable resources, not sustainably managed
4 = renewable resources, sustainably or renewably managed

Matrix	Traditional Criteria					Environmental Criteria				
Criterion / weight factor / Material	durability x4	cost x3	STC x1	flexibility x1	maintenance x1	recycled content x1	embodied energy x1	IAQ x3	raw materials x1	total points
CMU	3.5x4	3x3	3.5	1.5	3.5	2	2	3x3	2	46.5
Glazed CMU	4x4	2x3	3.5	1	4	2	1	4x3	2	47.5
gypsum board system	2x4	4x3	2	3	3	2	3	3x3	3	45
straw panels	2.5x4	3x3	1	1.5	3	4	3	3x3	4	44.5
operable partitions	1x4	1x3	2	4	2	1	3	3x3	2	29

Table 1

Analysis and Application of Matrix

According to the matrix, glazed concrete unit masonry is the preferred material for areas where durability and indoor air quality are the highest priorities. Regular CMU follows close behind, as long as water-based paints are used as the finish coating. Gypsum wallboard systems perform well, and could be considered in locations where impact resistance is not a concern. For example, partitions between classrooms could be made of gypsum wallboard, provided bookshelves, base cabinets, or other built-ins are installed, thereby protecting the lower wall area from impacts.

Operable partitions perform average or below on all counts except flexibility. But if installation of a folding partition allowed a school to avoid duplicating program space, one could factor in avoided impacts; in this case, operable partitions are a viable option.

Straw panel systems performed best in the environmental criteria. They are competitive with gypsum wallboard overall. The 1/2 point difference is within the margin of error for this methodology. In areas close to the straw panel manufacturing plants, this system could score higher than gypsum wallboard because of reduced energy use associated with shipping. A longer track record and some case studies in schools would help to raise confidence in this material.

Consider the following when selecting the right partition type for the right application:

- use the most benign material that can stand up to its proposed use
- adapt the matrix to local priorities and improving information
- consider use of gypsum wallboard where impact resistance is not an issue or can be mitigated
- use low-VOC finishes and observe best practices for IAQ in applying them
- when CMU is demolished, it should be recycled

Conclusions

There is no perfect system for building partitions in schools. The most commonly specified systems, however, are relatively favorable from an environmental standpoint. The greatest impact that can be made may be in improving the environmental performance of tried-and-true systems. This includes specifying high recycled content in CMU and gypsum board; reducing the VOC-emitting additives in wet compounds and adhesives; and using low-VOC finishes. There also is merit in limiting the use of CMU in locations where flexibility may be as important as durability.

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End Notes

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